(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 April 2003 (24.04.2003)

PCT

(10) International Publication Number
WO 03/034530 A2

(51) International Patent Classification[7]: **H01M 8/24**, 8/02

(21) International Application Number: PCT/GB02/04509

(22) International Filing Date: 4 October 2002 (04.10.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0124448.2 11 October 2001 (11.10.2001) GB
0127525.4 16 November 2001 (16.11.2001) GB

(71) Applicant *(for all designated States except US)*: **THE MORGAN CRUCIBLE COMPANY PLC** [GB/GB]; Morgan House, Madeira Walk, Windsor, Berkshire SL4 1EP (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **TURPIN, Mark, Christopher** [GB/GB]; c/o The Morgan Crucible Company plc, Morgan House, Madeira Walk, Windsor, Berkshire SL4 1EP (GB). **BOFF, James, Charles** [GB/GB]; c/o Phillips & Leigh, 5 Pemberton Row, London EC4A 3BA, Greater London EC4A 3BA (GB).

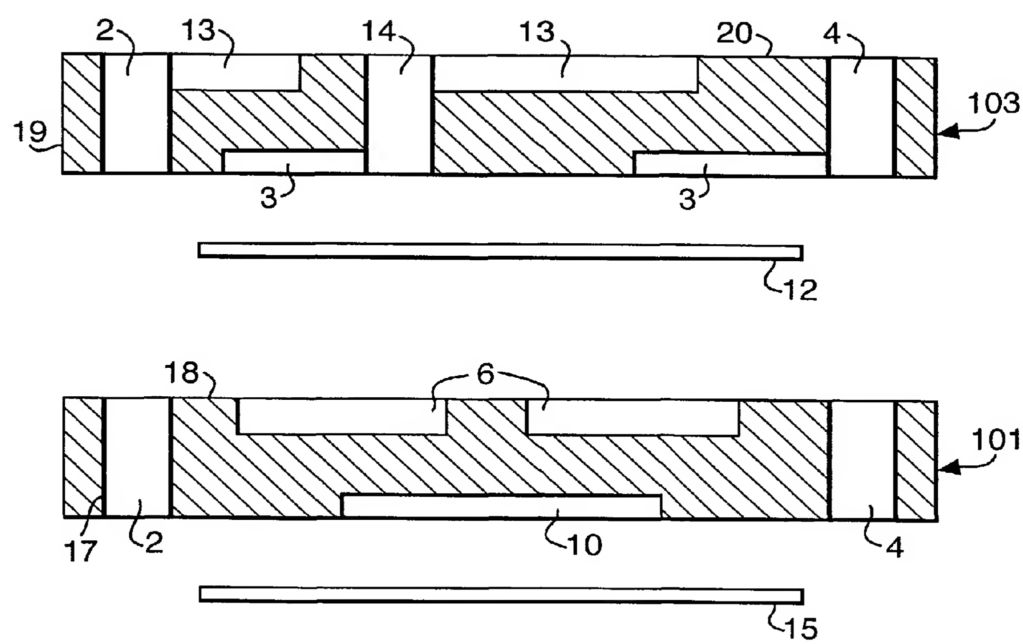
(74) Agent: **PHILLIPS & LEIGH**; 5 Pemberton Row, London EC4A 3BA (GB).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE,

[Continued on next page]

(54) Title: FUEL CELL OR ELECTROLYSER CONSTRUCTION



(57) Abstract: A fuel cell or electrolyer module, comprises: a) an electrically insulating housing comprising manifolds for operating fluids; b) a plurity of electrically conductive plates mounted in the housing with openings communicating to appropriate manifolds; c) means to make operative sealing contact with an adjacent like module.

WO 03/034530 A2

ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

FUEL CELL OR ELECTROLYSER CONSTRUCTION

This invention relates to fuel cells and electrolysers, and is particularly, although not exclusively, applicable to proton exchange membrane fuel cells and electrolysers.

Fuel cells are devices in which a fuel and an oxidant combine in a controlled manner to produce electricity directly. By directly producing electricity without intermediate combustion and generation steps, the electrical efficiency of a fuel cell is higher than using the fuel in a traditional generator. This much is widely known. A fuel cell sounds simple and desirable but many man-years of work have been expended in recent years attempting to produce practical fuel cell systems. An electrolyser is effectively a fuel cell in reverse, in which electricity is used to split water into hydrogen and oxygen. Both fuel cells and electrolysers are likely to become important parts of the so-called "hydrogen economy". In the following, reference is made to fuel cells, but it should be remembered that the same principles apply to electrolysers.

One type of fuel cell in commercial production is the so-called proton exchange membrane (PEM) fuel cell [sometimes called polymer electrolyte or solid polymer fuel cells (PEFCs)]. Such cells use hydrogen as a fuel and comprise an electrically insulating (but ionically conducting) polymer membrane having porous electrodes disposed on both faces. The membrane is typically a fluorosulphonate polymer and the electrodes typically comprise a noble metal catalyst dispersed on a carbonaceous powder substrate. This assembly of electrodes and membrane is often referred to as the membrane electrode assembly (MEA).

Hydrogen fuel is supplied to one electrode (the anode) where it is oxidised to release electrons to the anode and hydrogen ions to the electrolyte. Oxidant (typically air or oxygen) is supplied to the other electrode (the cathode) where electrons from the cathode combine with the oxygen and the hydrogen ions to produce water.

In commercial PEM fuel cells many such membranes are stacked together separated by flow field plates (also referred to as bipolar plates). The flow field plates are typically formed of metal or graphite to permit good transfer of electrons between the anode of one membrane and the cathode of the adjacent membrane.

WO97/50139 discloses a bipolar plate for a polymer electrolyte membrane fuel cell in which a conductive insert is moulded into a melt processable frame and in which gas passages are provided in the conductive insert.

WO01/80339 discloses a bipolar plate for a polymer electrolyte membrane fuel cell in which a conductive polymer insert is moulded into a non-conductive polymer frame and in which gas passages are provided in the non-conductive frame. Special tools are used to weld in the area surrounding ports through the plates. WO01/80339 discloses the use of ultrasonic welding to weld adjacent plates together but does not disclose the use of welding protrusions or formed sealing features to provide sealing.

GB 2006101 discloses the use of ultrasonic welding of sealing features in a fuel cell construction comprising a polymer frame with metal gauze electrodes surrounding a void, but was not concerned with sealing flow field plate separators and did not disclose the use of welding pips. So far as the applicants are aware the use of welding pips and sealing features to facilitate ultrasonic welding of flow field plate separators has not been proposed.

The flow field plates have a pattern of grooves on their surface to supply fluid (fuel or oxidant) and to remove water produced as a reaction product of the fuel cell. Various methods of producing the grooves have been described, for example it has been proposed to form such grooves by machining, embossing or moulding (WO00/41260), and by sandblasting through a resist (WO01/04982). In a sandblasting system, particles (such as sand, grit, fine beads, or frozen materials) are carried by a blast of air directed towards an article to be treated. The particles travel at a high speed, and on impacting the article abrade the surface.

The form of the flow field varies. Serpentine, linear, lattice and interdigitated flow fields have been suggested. In the majority of applications the reactants flow from one side of the plate to another but it has been proposed, for solid oxide fuel cells, to provide oxidant and reactant flow field in which the reactant gases flow radially outwards from centrally disposed manifolds (e.g. WO01/41239). This is to reduce the risk of back diffusion of oxidant into the fuel flow field causing premature combustion (and even explosions). Such problems do not apply to proton exchange membrane fuel cells as they operate at drastically lower temperatures (PEM fuel cells at ~80-95°C and SOFC fuel cells at ~850-1000°C).

To ensure that the fluids are dispersed evenly to their respective electrode surfaces a so-called gas diffusion layer (GDL) is placed between the electrode and the flow field plate. The gas diffusion layer is a porous material and typically comprises a carbon paper or cloth, often having a bonded layer of carbon powder on one face and coated with a hydrophobic material to promote water rejection.

An assembled body of flow field plates and membranes with associated fuel and oxidant supply manifolds is often referred to a fuel cell stack.

The fluorosulphonate membranes conventionally used need to have a certain amount of moisture to work and so typically a fuel cell stack also includes a humidification section for the fuel and optionally for the oxidant.

In operation a fuel cell generates waste heat and so conventionally, at intervals along the stack, cooling sections are provided in which coolant flowing through a coolant flow field draws heat from the stack. The conductivity of the flow field plates is relied upon to get heat from those membranes remote from the coolant section.

Such an arrangement has problems however since the efficiency of a stack is governed by the efficiency of the least efficient membrane electrode assembly in a stack (the same charge has to pass through each and every membrane electrode assembly in the stack). This means that:-

- If the cooling is not the same for each membrane it means that some membranes will be operating at different temperatures than other membranes, which means that they cannot all be operating at their most efficient.
- Membrane electrode assemblies remote from the coolant plate will lose most of their heat through the edge of the plate so leading to an uneven distribution of heat across the membrane electrode assembly. This leads to different efficiencies of operation across the membrane electrode assembly.
- If the sealing of a membrane electrode assembly to its adjacent flow field plates is not adequate this means that fuel and oxidant can mix. Such mixing can result in a complete failure of that membrane electrode assembly and so a complete failure of the stack.
- The sealing of the membrane electrode assembly to its adjacent flow field plates does not occur until the stack is fully assembled.

Additionally, a fuel cell stack is conventionally held together against the pressure of the reactant gases by a frame. The reactant gases exert their pressure over a considerable portion of the stack area and so the forces generated are high. This means that the frame must be correspondingly robust. This frame often contributes most of the weight of the assembled stack. It would be advantageous if less massive means could be used to hold a stack together.

The applicants have realised that many of the problems of fuel cells can by overcome by the provision of pre-assembled modules of flow field plates and coolant flow field so that, individually or together:-

- The sealing of each individual membrane can be done in a controlled manner.
- The integrity of the sealing can be checked before assembly of the stack.
- Coolant can be supplied to each membrane electrode assembly – so improving uniformity of conditions between the membrane electrode assemblies.
- Coolant can be supplied across the whole area of each membrane electrode assembly – so improving uniformity of conditions across the membrane electrode assemblies.
- Provision of sealed units taking the majority of the bursting pressure from reactant gasses can permit a reduction in mass of the frame for securing the stack.
- the pre-assembled modules separate the fluid manifolds in an electrically insulating housing to reduce stray currents through the coolant.

Accordingly, the present invention provides a fuel cell or electrolyser module, comprising:-

a) an electrically insulating housing comprising manifolds for operating fluids;

b) a plurality of electrically conductive plates mounted in the housing with openings communicating to appropriate manifolds

c) means to make operative sealing contact with an adjacent like module.

Advantageously the fuel cell or electrolyser module comprises:-

a) one or more cells comprising:-

i) a first plate secured to;

ii) a second plate ;

iii) the first plate and second plates defining on opposed inner surfaces an oxidant flow field and a fuel flow field; and

iii) a membrane electrode interposed between the fuel flow field and the oxidant flow field;

b) a coolant flow field in contact with one or more of the electrically conductive plates; and

c) means to make operative sealing contact with an adjacent like module.

The invention further provides a fuel cell or electrolyser comprising a plurality of such fuel cell modules in operative combination with each other.

The modules may be formed from a plurality of flow field plates having a plurality of protrusions formed integrally on at least one surface, said protrusions being adapted in use to join the flow field plate to an adjacent flow field plate. The protrusions may comprise sealing features. Advantageously the material of the flow field plate is such that it may be welded to the adjacent plate, preferably by ultrasonic welding. The flow field plates may comprise integrally formed protrusions or indentations adapted to engage with complementary protrusions on an adjacent plate.

The flow field plates may comprise one or more electrically conductive inserts in a non-conductive frame, and fluid manifolds may be formed in the one or more electrically conductive inserts, or in the non-conductive frame, or both. Preferably the fluid manifolds are formed in the non-conductive frame. The electrically conductive inserts may comprise an electrically conductive polymeric composite material, or may be any other suitable conductive material.

Further features of the invention will be apparent from the claims and the following description with reference to the drawings in which:-

Figs. 1 and 2 show either side of a conventional bipolar plate;

Fig. 3 shows a coolant plate;

Fig. 4 shows a conventional arrangement of bipolar plates, membrane electrode assemblies, and coolant plates;

Figs. 5 & 6 show either side of a novel flow field plate for use in the present invention;

Fig. 7 shows an assembled module in accordance with the present invention;

Figs. 8 and 9 show alternative arrangements of flow field plates and membrane electrodes in accordance with the present invention;

Fig. 10 shows an alternative embodiment flow field plate;

Fig. 11 shows schematically in plan (11a), and underside (11b) a frame and conductive plate for use in construction of an alternative embodiment of fuel cell module;

Fig. 12 shows schematically in plan (12a), and underside (12b) a frame and conductive plate for use in construction of an alternative embodiment of fuel cell module;

Fig. 13 shows schematically in plan (13a), and underside (13b) a frame and conductive plate for use in construction of an alternative embodiment of fuel cell module;

Fig. 14 shows schematically in plan (14a), and underside (14b) a frame and conductive plate for use in construction of an alternative embodiment of fuel cell module;

Fig. 15 shows shows schematically in plan (15a), and underside (15b) an assembled fuel cell module incorporating the integers of Figs. 11 to 14;

The invention is described with reference to a fuel cell but the same considerations apply to electrolysers.

Figs. 1 and 2 show either side of a conventional bipolar plate 1 (except for reference 16 which is described below with reference to one embodiment of the present invention). Fig. 1 shows the fuel side of bipolar plate 1 and Fig. 2 shows the oxidant side of bipolar plate 1.

Bipolar plate 1 has six through holes 2,4,5,7,9 and 11 (whose purpose is described below). Fuel supply port 2 connects with a channel on the bipolar plate surface defining a fuel flow field 3 leading to fuel drain port 4. Oxidant supply port 5 connects on the reverse of the bipolar plate 1 with a channel defining an oxidant flow field 6 leading to an oxidant drain port 7.

As shown in Fig. 3 a coolant plate 8 (which is conventional except for reference 16, which is described below with reference to the present invention) has corresponding through holes 2,4,5,7,9 and 11. Coolant supply port 9 connects on one or both surfaces with channels defining a coolant flow field 10 leading to a coolant drain port 11.

As shown in Fig. 4, conventionally a plurality of bipolar plates 1 are stacked with intervening membrane electrode assemblies 12, and periodically coolant plates 8 are interposed. The through holes 2,4,5,7,9 and 11 are aligned in registration and seals have to be provided around each hole to prevent leakage of oxidant, fuel, or coolant into regions where it is not wanted.

In a fuel cell module according to the present invention, as shown in Figs. 8 and 9, a first plate 101 is secured to a second plate (102,103) with a membrane electrode interposed. The plates are secured together by any means that ensures that the plates are electrically insulated from each other. The plates 101, 102, 103 define on their inner surfaces an oxidant side 18 and a fuel side 19. Appropriate sealing is provided around through holes 2,4,5,7,9 and 11 to ensure that fuel only gets to the fuel side 19 of membrane 12, oxidant only gets to the oxidant side 18 of membrane 12, and that coolant does not reach the membrane. A coolant side 17 is provided to the outer surface of either or both of the first or second plates. Sealing integers may be provided about each of through holes 2,4,5,7,9 and 11 adapted to engage with complementary sealing integers on an adjacent corresponding fuel cell module. The sealing integers and complementary features may, for example, be interengaging lips and grooves and the lips may either be integral with the plates or separate sealing rings seated in grooves on a plate. Preferably sealing is adhesive free so as to permit ready separation and removal of modules from a stack.

As examples of specific module constructions, Fig. 8 shows a plate 101 having on an outer surface a coolant side 17 corresponding to Fig. 3 and on an inner surface an oxidant side 18 corresponding to Fig. 2. Plate 102 has on an inner surface a fuel side corresponding to Fig. 1 with the reverse surface (not shown) either plain, or having complementary features to form a coolant flow field with the coolant flow field 10 on coolant side 17. The complementary features may for example comprise channels corresponding to that on the coolant side, so that the flow field extends into plate 102, or ridges adapted to engage and seal the coolant flow field on plate 101. Of course, the coolant side could be on the same plate as the fuel side, with the outer surface of plate 101 being plain, or having complementary features to form a coolant flow field with the coolant flow field on the coolant side. This arrangement is not illustrated.

Figs. 7 and 9 show an alternative arrangement in which plate 101 is as in Fig. 8 whereas plate 103 incorporates a novel humidification arrangement as shown in detail in Figs. 5 and 6. (Fig 7 is a section along line A of Figs. 2,3,5 and 6).

Fig.5 shows a humidification side 20 of plate 103 and Fig. 6 shows the fuel side 19 of plate 103. Fuel entering port 2 passes along humidification channel 13 until it reaches via 14, which passes from the humidification side 20 to the fuel side 19 of plate 103. At the fuel side 19 the fuel passes along the fuel flow field 3 to fuel drain port 4. As shown in Fig. 7, the module comprises an additional element, namely a humidification membrane 15. This may be secured either over the coolant channel (as shown), or over the humidification channel, or it may be supplied as a separate article when assembling the fuel cell. Preferably the membrane is recessed into one or other plate surface so that the unrecessed parts of the plate provide electrical connectivity with an adjacent plate. If this is not done, then separate means must be provided to ensure that such electrical connectivity occurs.

When a pair of modules as shown in Fig. 7 are placed next to each other, hydrogen flowing in the humidification channel of one module can be humidified by water from the coolant channel permeating through the humidification membrane. The membrane may be of any material that is permeable to water but relatively impermeable to hydrogen.

It is generally more important to humidify the fuel side rather than the oxidant side (as water is produced on the oxidant side during operation of the fuel cell). However, if it is desired to humidify the oxidant, oxidant humidification ports 16 may be provided in plate 101 communicating from the coolant flow field 10 to the oxidant flow field 6. These ports may either be plugged with a wick of water permeable material, or may communicate to a membrane of such material within either the coolant flow field or oxidant flow field.

The applicants have realised that it may be possible to omit some of the channels used in conventional fuel cell arrangements. Fig. 10 shows an alternative form of flow field in which flow field plate 402 is hexagonal annular in form having a fuel supply aperture 403. Branching flow field pattern 404 (part shown) connects fuel supply aperture 403 to a fuel drain 405 which leads to fuel drainage port 408. Land 406 is configured to receive seals and this configuration may take place either with the formation of the flow field or in a separate step.

The oxidant flow field on the adjacent flow field plate is the reverse, with oxidant flowing in from the outer edge of the flow field plate to an inner drain communicating with oxidant drain port 409. On the reverse of the oxidant flow field plate is a coolant track. Coolant inlet port 411 communicates via this coolant track to coolant outlet port 412. An assembly of an oxidant/coolant flow field plate, a membrane electrode assembly, and a fuel flow field plate can be sealed together to form a module.

In this arrangement the fuel flow is divergent and the oxidant flow is convergent so providing a countercurrent radially directed fluid flow each side of the membrane electrode (using "radial" in the sense of moving towards or radiating from a point and not in the limited sense of referring to the radius of a circle).

Such an arrangement in which fuel and oxidant flow in a countercurrent radial manner on either side of the membrane electrode assembly has several advantages in operation. Firstly one has a countercurrent flow between the fuel and the oxidant which maintains a relatively even pressure differential across the membrane electrode compared with conventional bipolars, which tend to have a cross-flow arrangement. Such a relatively even pressure differential means that the membrane is under a relatively reduced stress. Secondly, the pressure is more evenly distributed across the width of the stack and this means that the forces acting on the bipolar plates are evenly distributed, lessening the risk of a plate breaking or deforming. Further, the evenness of pressure distribution leads to an improved uniformity of electricity generation across the membrane electrode.

Preferred materials for the plate are graphite, carbon-carbon composites, or carbon-resin composites. However the invention is not restricted to these materials and any material of suitable physical characteristics may be used. For example, any electrically conductive polymer that does not react detrimentally to the materials of the membrane electrode assembly, for example the materials disclosed in WO01/80339, WO01/60593, GB2198734, US6180275, WO00/30202, WO00/30203, WO00/25372, and WO00/44005. The frame can be made of any suitable insulating material but thermoplastic materials offer some advantages in construction.

The plates may comprise one or more electrically conductive inserts and a non-conductive frame. Such an arrangement may be created by insert injection moulding the non-conductive frame onto the electrically conductive inserts, by injection moulding the electrically conductive inserts into the frame, by welding the parts together, or by any other appropriate means. Insert injection moulding of the frame about the conductive insert can be used as described in

WO01/80339 and WO97/50139 and, in particular, the method of WO01/80339 is advantageous. Fluid manifolds (for reactant gases and coolants) can be positioned in the one or more electrically conductive inserts, or in the non-conductive frame, or both.

A plurality of such modules may be connected in operative combination, and with electrical connectivity between adjacent modules, to provide a fuel cell stack in which each membrane electrode has an adjacent cooling flow field and the appropriate ports on the plates are connected and sealed appropriately to at least one adjacent plate (whether part of the same module or an adjacent module).

A further embodiment of the invention is shown in Figs. 11 to 15. A fuel cell module 900 (Fig. 15) comprises an electrically insulating housing 901 incorporating on its outer surface electrically conductive plates 902, 903 bearing coolant flow fields defined by grooves 904 in their surface. The grooves could if desired be replaced by a lattice type flow field as is conventionally known or by any other form of suitable flow field.

The housing 901 incorporates a plurality of openings or ports defining manifolds for operating fluids. Port 905 defines a coolant inlet manifold and port 906 defines a coolant outlet manifold. Port 907 defines a fuel inlet manifold and port 908 defines a fuel outlet manifold. Port 909 defines an oxidant inlet manifold and port 910 defines an oxidant outlet manifold. Apertures 911 define holes for receiving bolts (not shown) for securing two or more such modules together to form a stack.

Sealing protrusions 912 are shown surrounding ports 907,908,909 and 901 on one face of the module designed to mate with and seal to the corresponding ports of an adjacent module.

A sealing rib 913 is shown designed to mate with an adjacent module and to seal the coolant flow field.

The housing 901 comprises a series of sub-assemblies each comprising a non-conductive frame and a conductive plate insert. The non-conductive frame may be insertion injection moulded onto the conductive plate insert, or two or more sub-frames can be joined to trap the conductive plate insert (for example by ultrasonic welding and/or the use of hot-melt adhesives), or by any other suitable means. These sub assemblies trap membrane electrodes as discussed below and are secured together (preferably by welding) in the manner discussed below.

Fig. 11 shows a first sub-assembly 914, which comprises electrically conductive plate 902 mounted into a frame 915 comprising an electrically insulating material (e.g. an injection moulded plastic) to or in which the plate 902 is secured. On one face plate 902 has the coolant flow field, and on the reverse face an oxidant outflow channel 917 with a surrounding recess 916 to receive a membrane capable of transferring water from one face to side to the other. The oxidant outflow channel 917 extends from the oxidant outlet port 910 to an internal oxidant communication port 918.

Fig. 12 shows a second sub-assembly comprises an electrically insulating frame 919 in which is mounted an electrically conductive plate 920 comprising on one face a hydrogen humidification channel 921, and on the reverse an oxidant flow field 922. The electrically conductive plate has a central aperture 923, which receives a non-conductive core 924, having an aperture defining a core manifold 925.

Fig. 13 shows a third sub-assembly comprising an electrically insulating frame 926, in which is mounted an electrically conductive plate 927, comprising on one face a hydrogen flow field 928, and on the reverse an oxidant flow field 929. The electrically conductive plate has a central aperture 923, which receives a non-conductive core 924, having an aperture defining a core manifold 925 as in Fig. 12. The hydrogen flow field 928 exemplified is of the open-ended type whereas the oxidant flow filed exemplified is of the interdigitated type. This arrangement provides some advantages in operation of fuel cells. When the fuel is hydrogen, consumption of fuel leads to a low pressure drawing more fuel into contact with the membrane electrode. For the oxidant, when the oxidant is air, consumption of oxygen leaves nitrogen in its place and this can hamper the diffusion of oxygen into contact with the membrane electrode. By using an interdigitated flow field, air is driven through the gas diffusion layer, so helping to maintain oxygen pressure at the membrane electrode.

Fig. 14 shows a fourth sub-assembly comprising an electrically insulating frame 930, in which is mounted an electrically conductive plate 903, comprising on one face a hydrogen flow field 931, and on the reverse a coolant flow field 932.

The assembled module of Fig. 15 comprises one each of the first, second, and fourth sub-assemblies and one or more of the third sub-assemblies.

The sub-assemblies are joined together with membrane electrode assemblies interleaved between the second and third-sub-assemblies; between each of the third sub-assemblies if more than one; and between the third and fourth-sub assemblies.

Joining can conveniently be by laser welding the internal joints between the non-conductive cores in the second and third sub-assemblies; subsequently or simultaneously welding the outer frames together, and finally welding on the first and fourth sub-assemblies. Other methods of joining the parts – e.g. by ultrasonic welding, are intended to be encompassed by this invention.

When insert injection moulding is used, those passages for transmission of fluid from the frame to the relevant plate (e.g. oxidant outlet 917) can be kept open in manufacture by using a sacrificial material that can be washed out after forming the frame about the plate. As one alternative, the frame can be made in two or more parts that are joined together. By forming the passages for transmission of fluid from the frame to the relevant plate in one or more of the frame parts, and then joining the parts together (e.g. by ultrasonic welding and/or by use of hot melt adhesives), one can provide a submerged manifold or track leading from the frame to the conductive plate. This permits a continuous ridge seal to be provided around the graphite plate so providing improved sealing against the membrane electrode.

The module must have suitable means for operatively connecting the ports with an adjacent like module, but this does not preclude the use of separate sealing integers (e.g. O-ring) to facilitate sealing between the ports of adjacent modules.

Further features that can be included in such a module include means to show that the module is in operative order. For example, an LED can be mounted on the module with appropriate electronic circuitry such that when the module is in operation the LED is lit. Failure of a module would then be readily apparent allowing easy detection and replacement in comparison with existing stack designs.

Advantages of this form of construction include:-

a) the coolant water is well isolated from the membrane of the membrane electrode. This means that lower purity water than is conventionally used may be used for coolant. [Conventionally, highly pure water needs to be used to avoid contamination of the membrane with metal salts].

b) This tolerance of less pure water means that water/ethylene glycol or like low-freezing point coolants can be used which is advantageous for low temperature use.

c) By providing a housing that is welded together, a strong assembly results that can mean a lessened requirement for a strong frame for a fuel cell stack.

d) Using an interdigitated oxidant flow field to force air in and flush nitrogen out, and an open ended fuel flow field to give uniform fuel distribution, provides the fuel cell with the optimum geometry for the differing chemistries of either side of the membrane electrode assembly.

The separate integers described above may form inventions in their own right or in combination and the present application is intended to cover any novel and inventive integer or combination of integers disclosed herein. In particular the humidification arrangements and plate designs disclosed may be used in applications outside the scope of the claims, for example in non-modular fuel cell or electrolyser stacks.

CLAIMS

1. A fuel cell or electrolyser module, comprising:-
   a) an electrically insulating housing comprising manifolds for operating fluids;
   b) a plurality of electrically conductive plates mounted in the housing with openings communicating to appropriate manifolds
   c) means to make operative sealing contact with an adjacent like module.

2. A fuel cell or electrolyser module as claimed in Claim 1, in which the housing comprises a plurality of insulating frames having one or more electrically conductive plate inserts.

3. A fuel cell or electrolyser module as claimed in Claim 2, in which the frames are insert injection moulded onto the conductive plates.

4. A fuel cell or electrolyser module as claimed in Claim 1, in which some at least of the plates have apertures connected to an insulating core defining a core manifold.

5. A fuel cell or electrolyser module as claimed in Claim 4, in which the fuel flow fields on the conductive plates communicate with the core manifold.

6. A fuel cell or electrolyser module as claimed in Claim 4, in which fuel humidifiers on the plates communicate with the core manifold.

7. A fuel cell or electrolyser module as claimed in any one of Claims 1 to 6, and comprising at least one plate having an open ended fuel flow field on one face and an interdigitated oxidant flow field on the reverse face.

8. A fuel cell or electrolyser module as claimed in any one of Claims 1 to 7, in which the means to make operative sealing contact with an adjacent like module comprise co-operating sealing members capable of forming an adhesive-free seal.

9. A fuel cell or electrolyser module as claimed in any one of Claims 1 to 8, comprising:-
   a) one or more cells comprising:-
      i) a first electrically conductive plate secured to;
      ii) a second electrically conductive plate ;
      iii) the first electrically conductive plate and second electrically conductive plate defining on opposed inner surfaces an oxidant flow field and a fuel flow field; and
      iv) a membrane electrode interposed between the fuel flow field and the oxidant flow field; and
   b) a coolant flow field in contact with one or more of the electrically conductive plates.

10. A fuel cell or electrolyser module, as claimed in Claim 9, in which integers are provided on one of the first or second plates and complementary integers on the other of the first or second plates, the integers and complementary integers of adjacent modules defining between them at least part of the coolant flow field.

11. A fuel cell or electrolyser module, as claimed in any one of Claims 9 to 10, in which:-
    a) the first plate comprises the oxidant flow field and the coolant flow field
    b) the second plate comprises the fuel flow field and, on its outer surface, a fuel humidification flow field.

12. A fuel or electrolyser module, as claimed in any one of Claims 1 to 11, having countercurrent radially directed fuel and oxidant flow fields on either side of a membrane electrode assembly.

13. A fuel cell module as claimed in any one of Claims 1 to 12, having a humidifier internal to the module for humidification of incoming fuel.

14. A fuel cell module as claimed in Claim 13, in which the humidifier internal to the module comprises a humidification flow field opposed to a coolant flow field with a water permeable membrane disposed therebetween.

15. A fuel cell module as claimed in Claim 14, in which the humidification flow field is on one face of a plate and communicates through a via with a fuel flow field on the reverse face of said plate.

16. A fuel cell module as claimed in Claim 15, in which the humidifier internal of the module comprises a humidification flow field opposed to an outgoing oxidant flow field with a water permeable membrane disposed therebetween.

17. A fuel cell module as claimed in Claim 16, in which the fuel passing through the humidification flow field passes in a countercurrent sense to oxidant flowing in the outgoing oxidant flow field.

18. A fuel cell or electrolyser stack comprising a plurality of the modules of any one of Claims 1 to 17, in operative combination with each other.

19. A flow field plate for a fuel cell or electrolyser module as claimed in any one of Claims 1 to 17, comprising on one face a humidification flow field communicating through a via with a fuel flow field on the reverse face.

Fig.1.

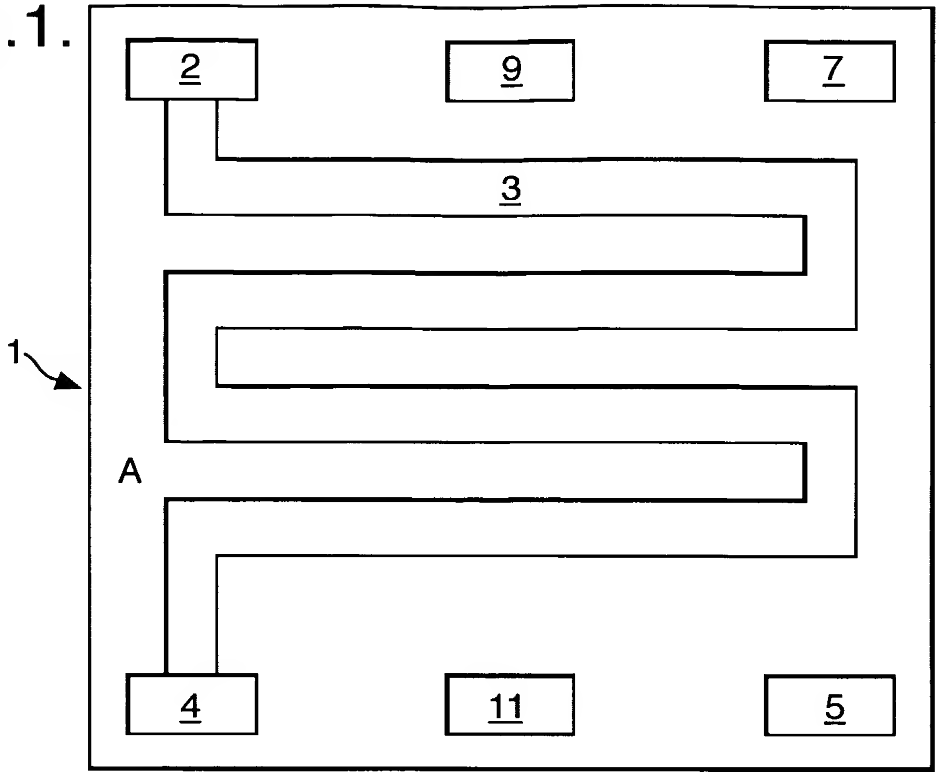


Fig.2.

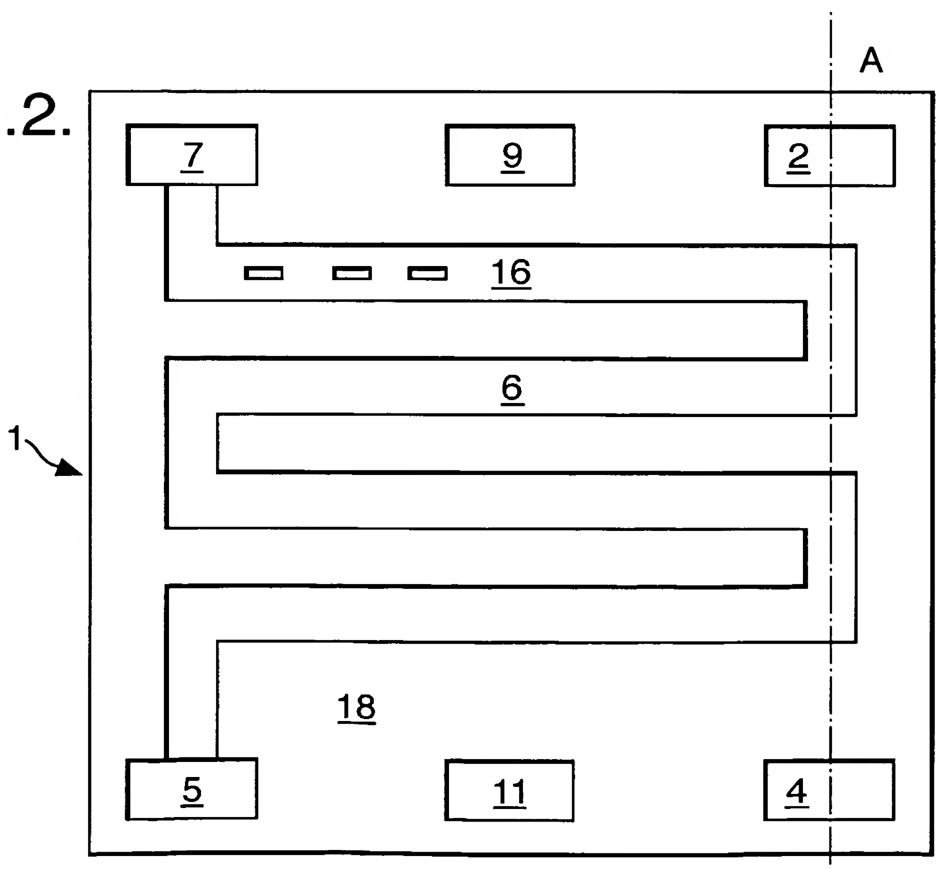


Fig.3.

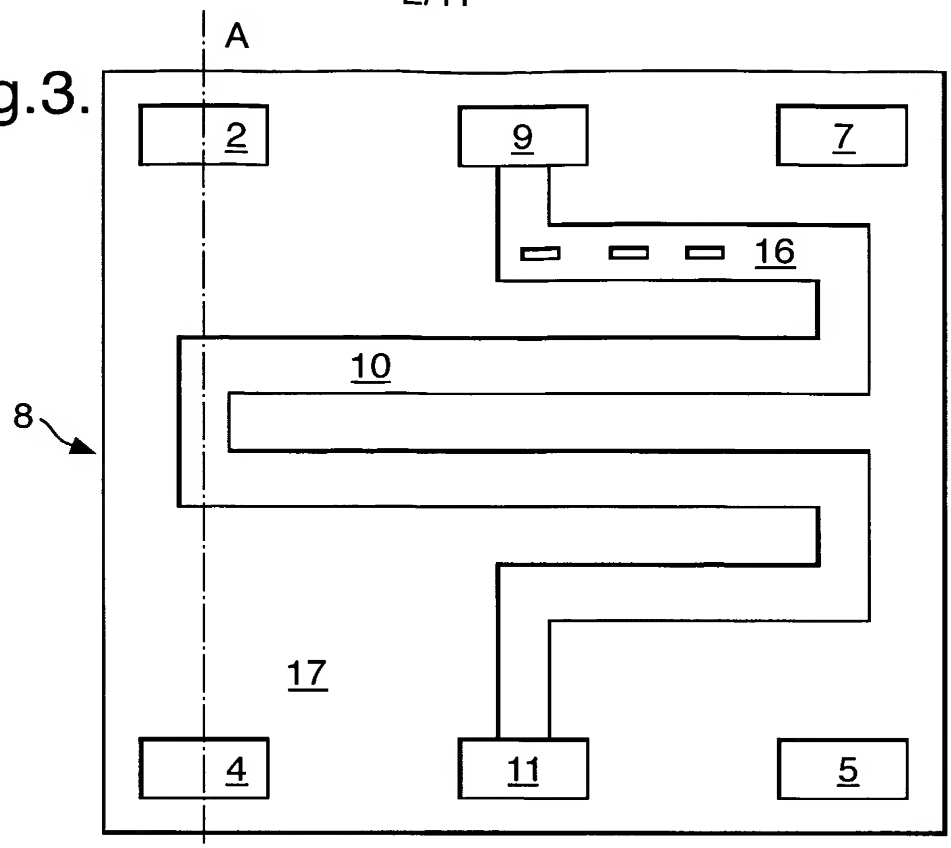


Fig.5.

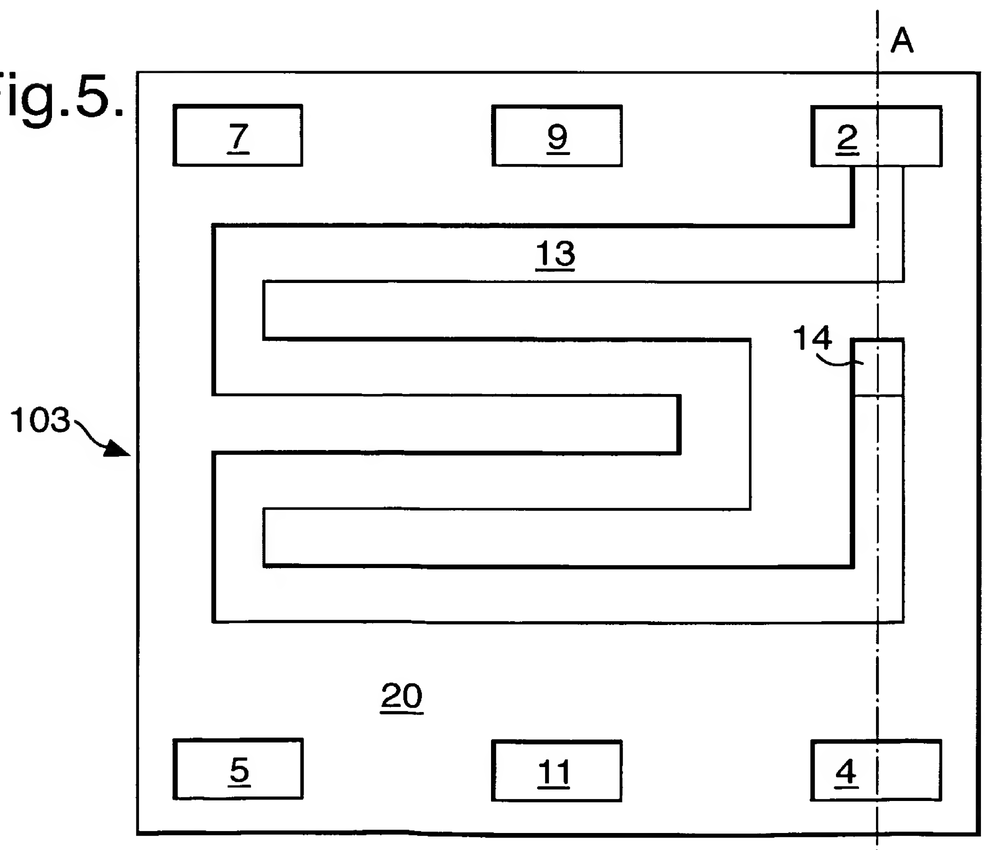


Fig.4.
Prior Art

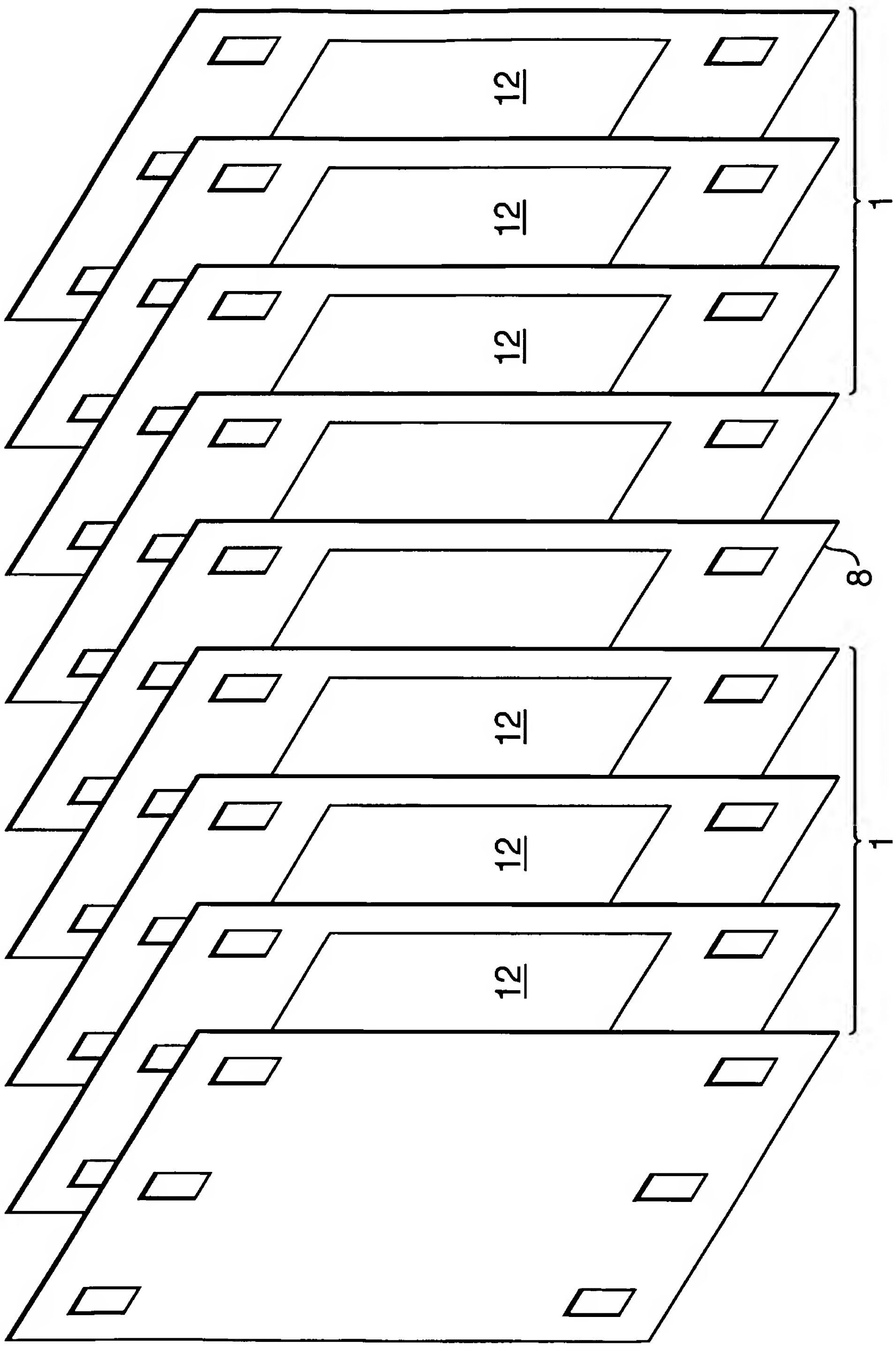


Fig.6.

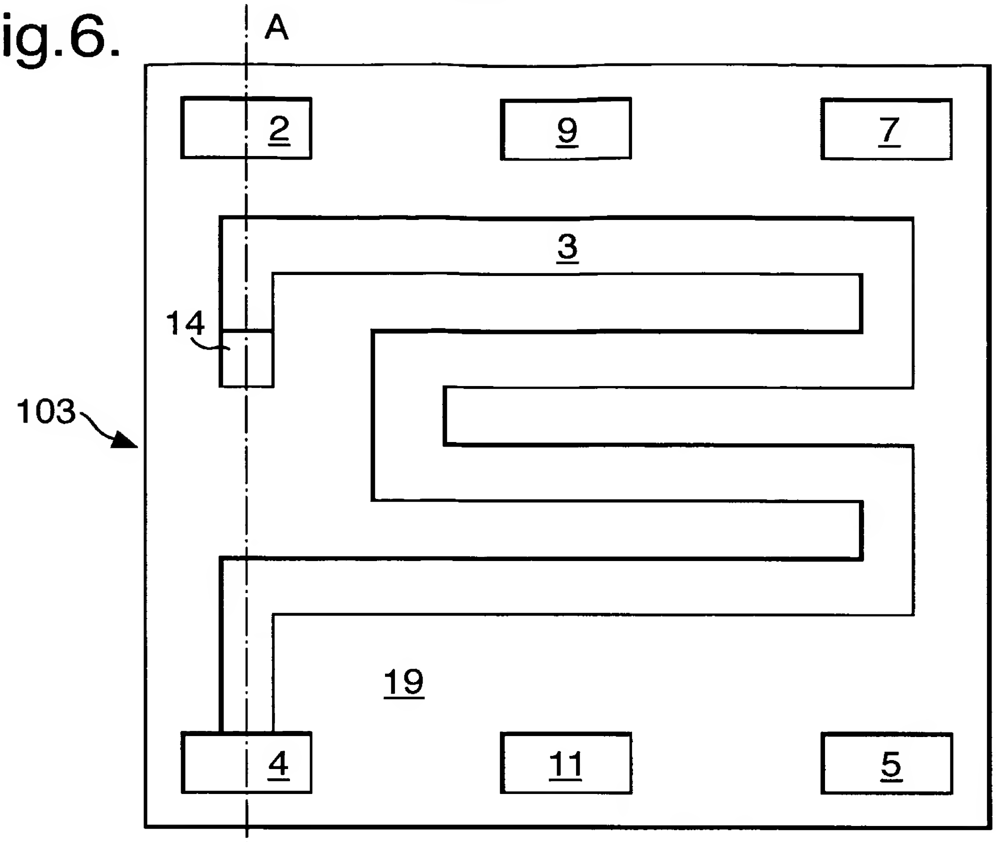


Fig.7.

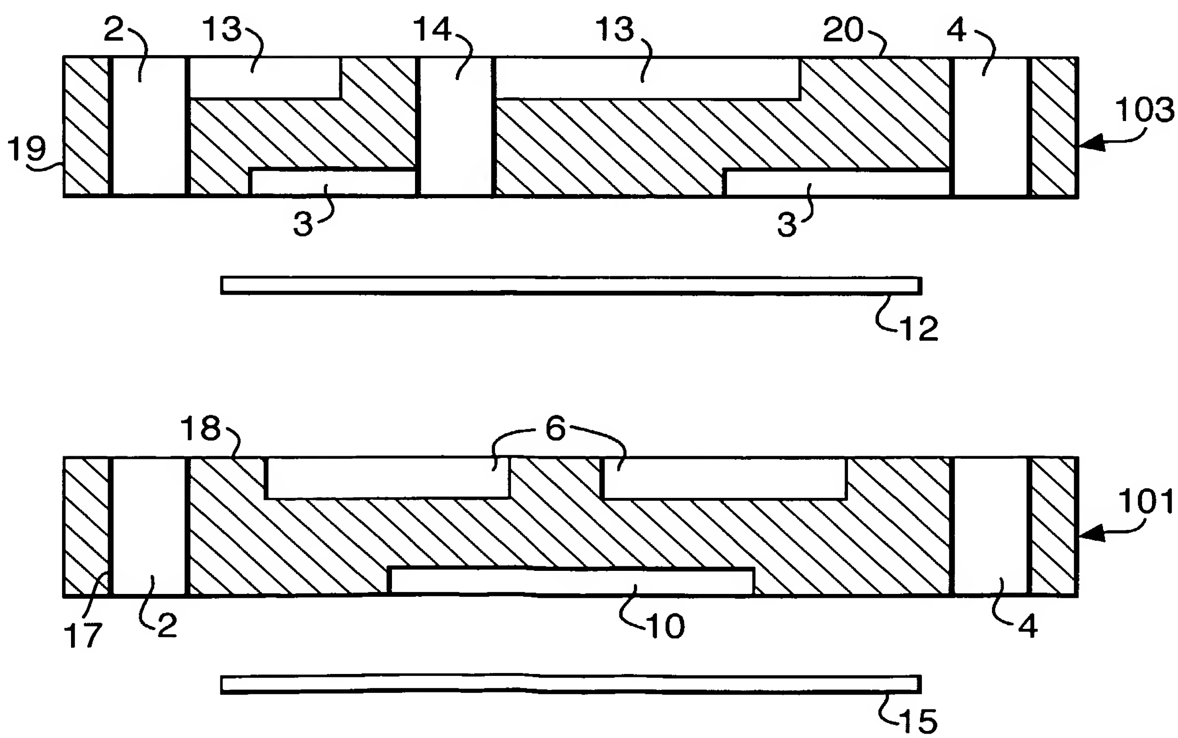


Fig.9.

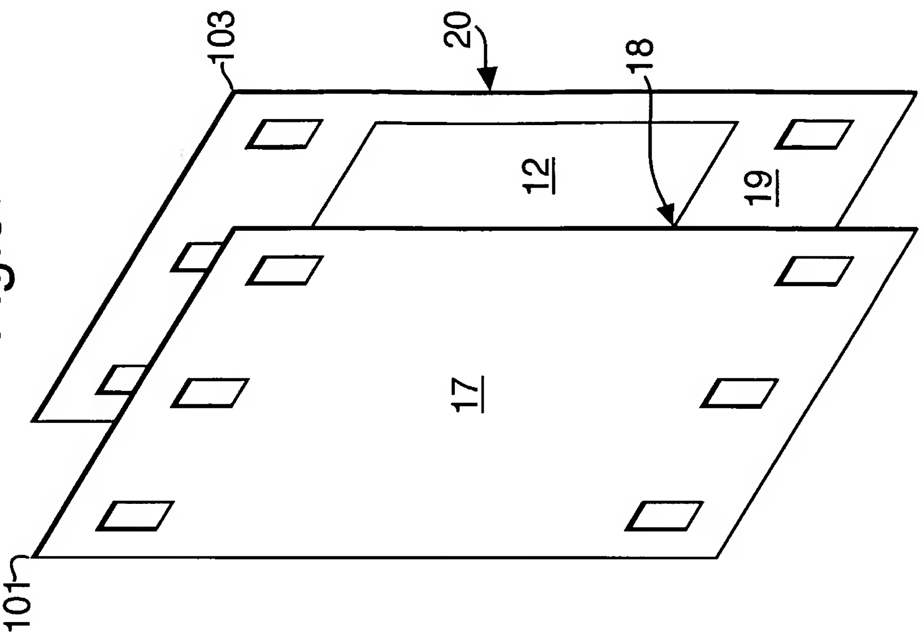
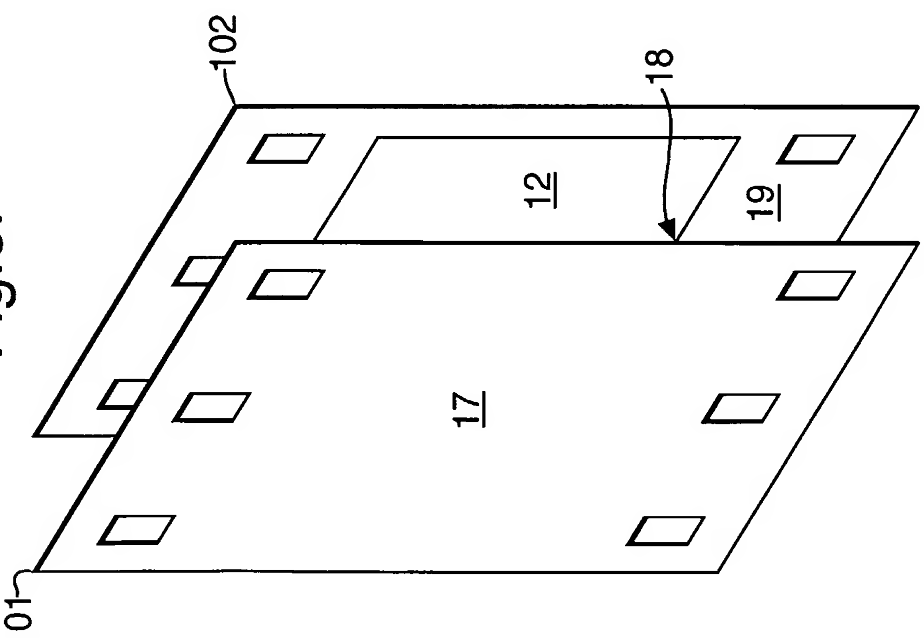


Fig.8.



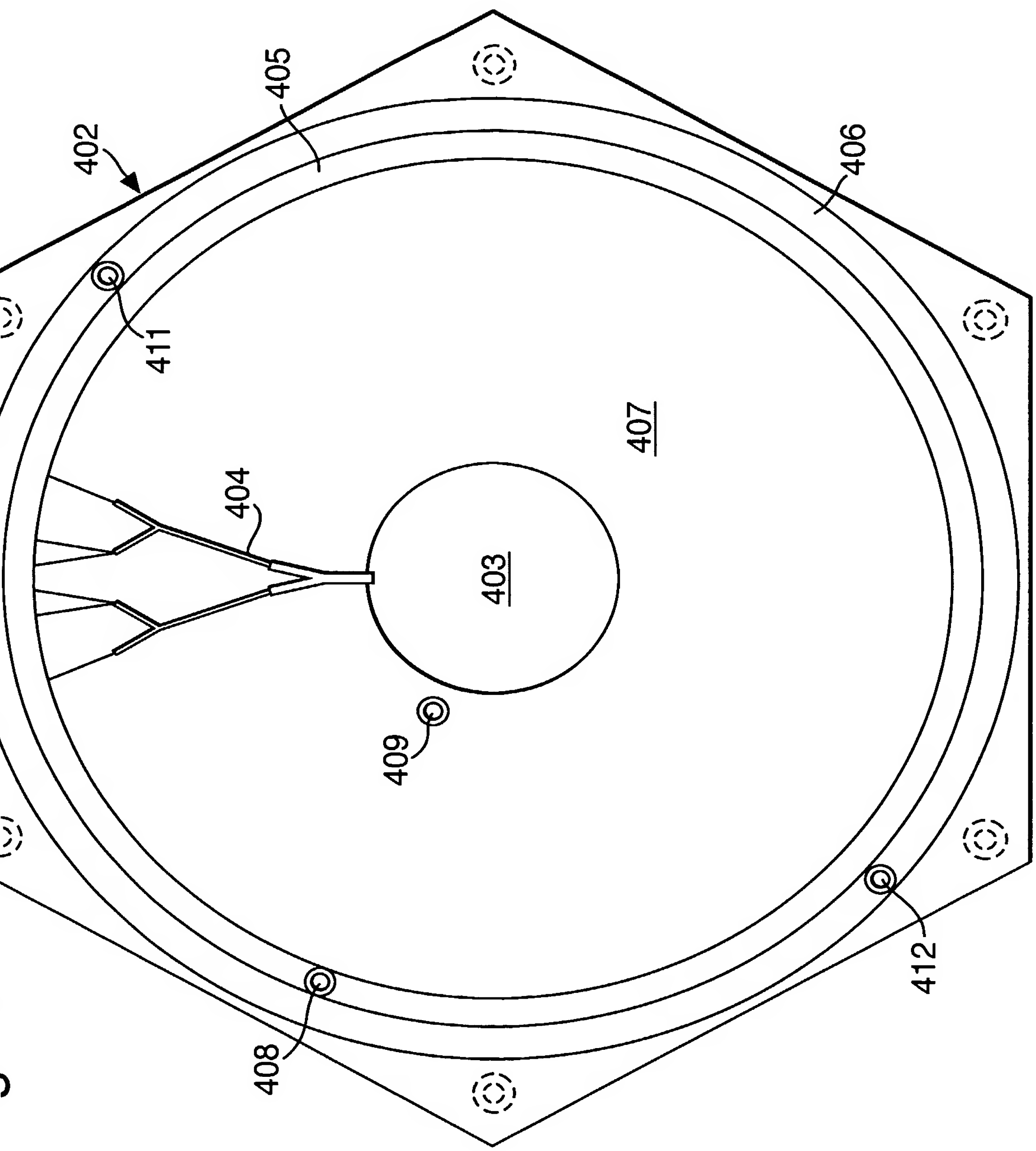


Fig.10.

Fig. 11(a).

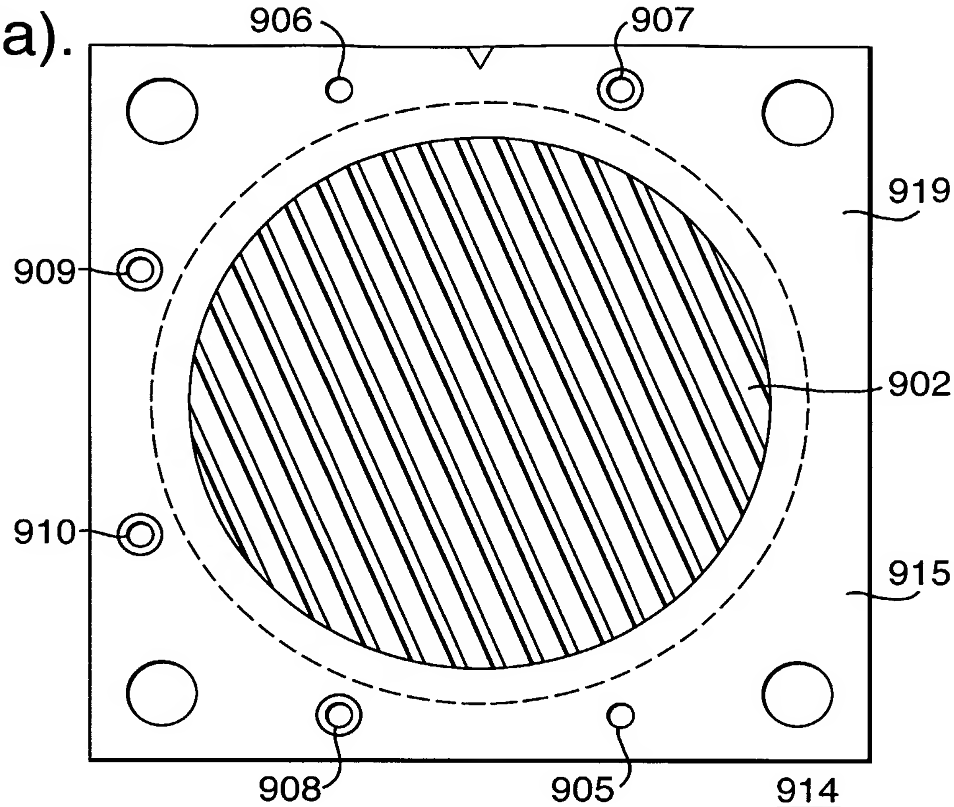


Fig. 11(b).

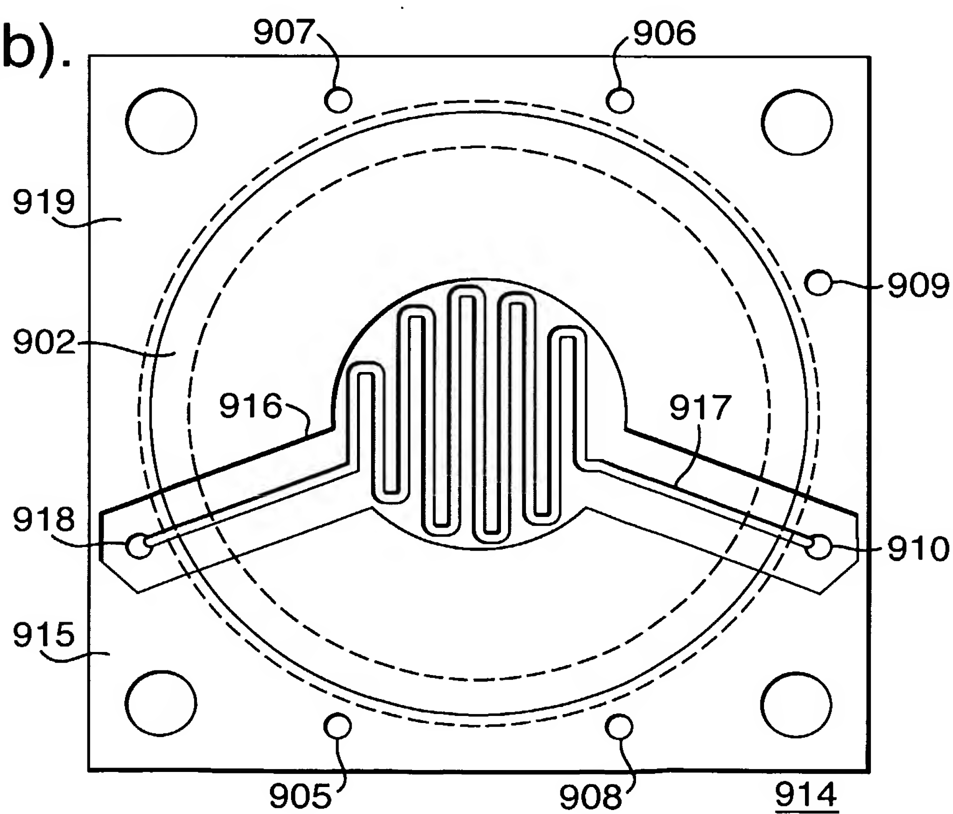


Fig.12(a).

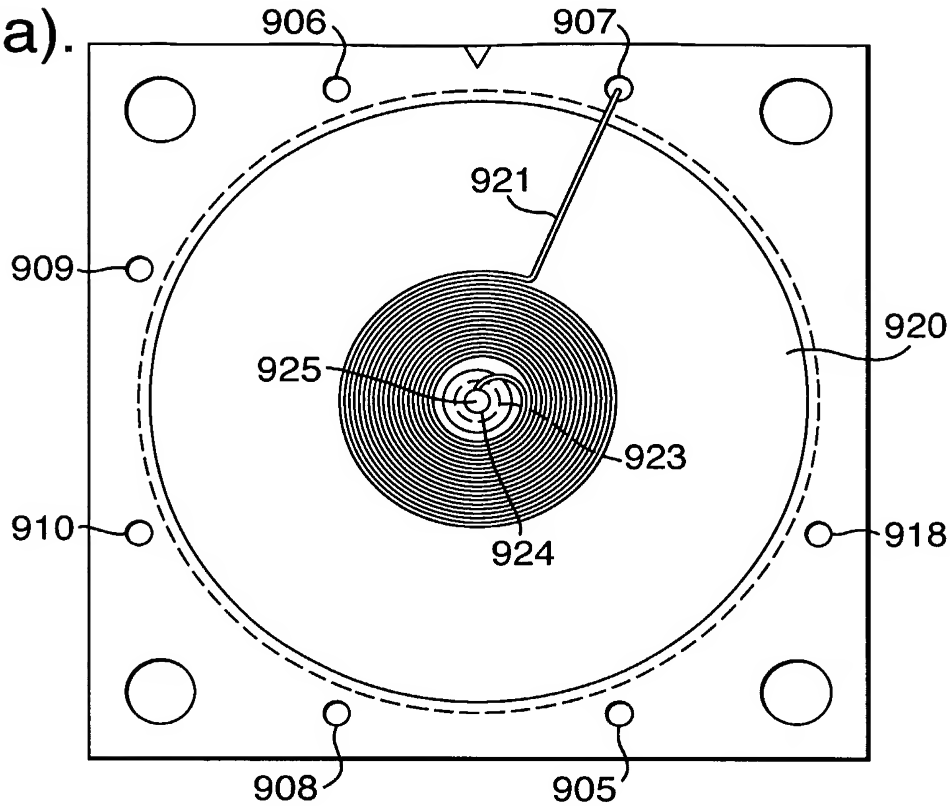


Fig.12(b).

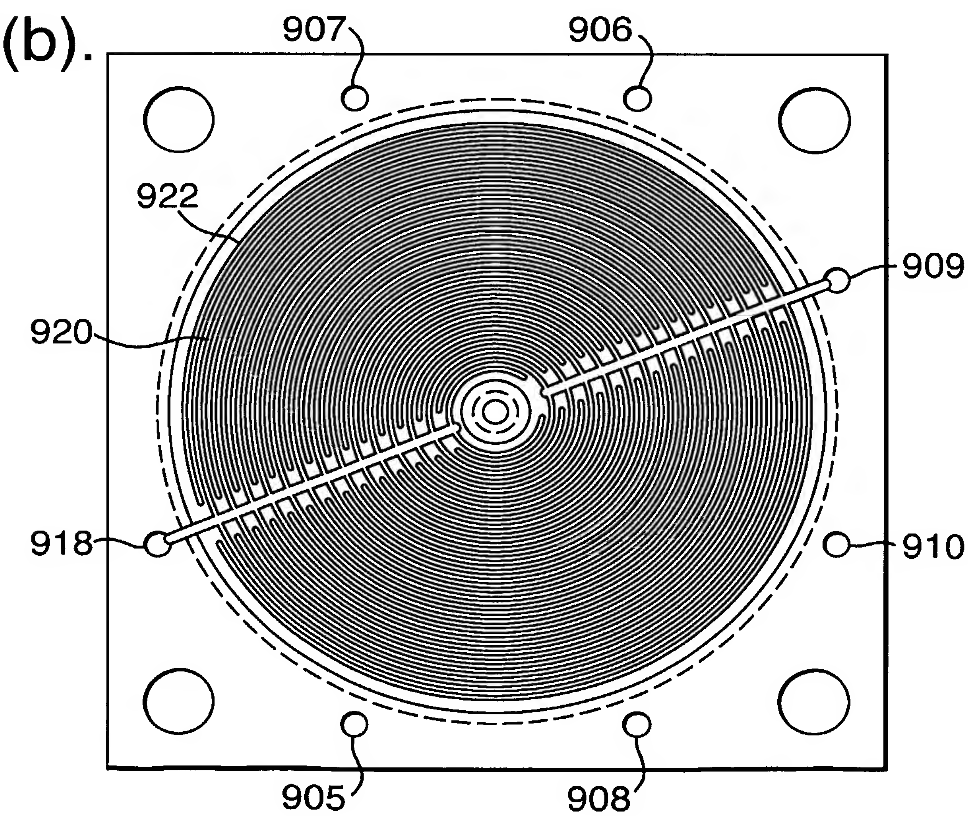


Fig.13(a).

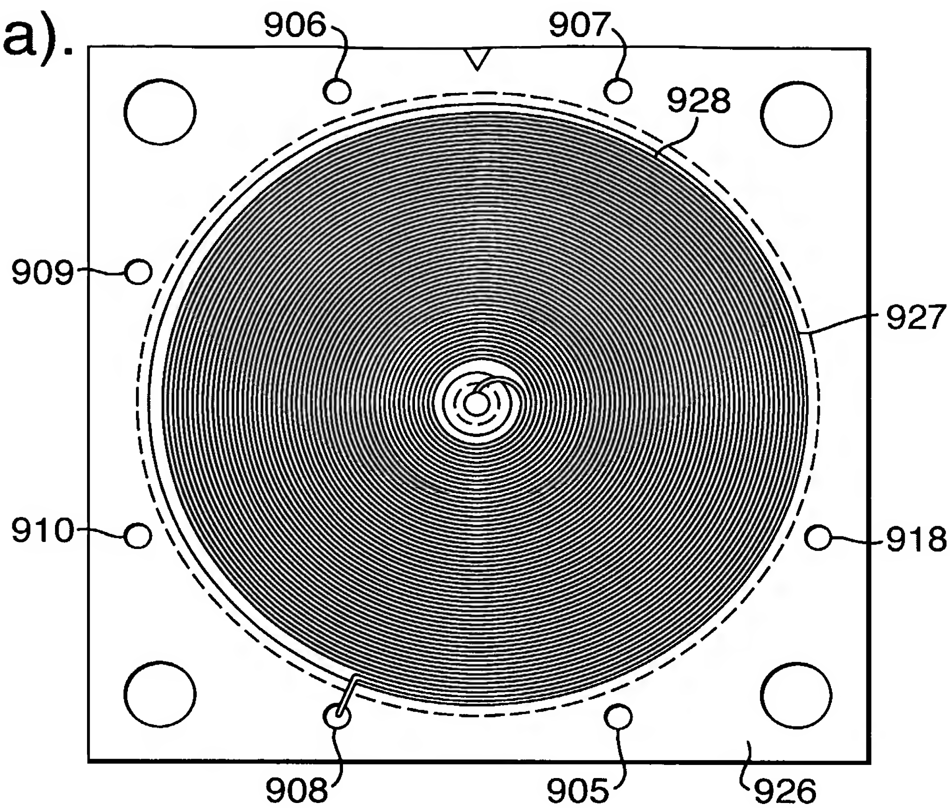


Fig.13(b).

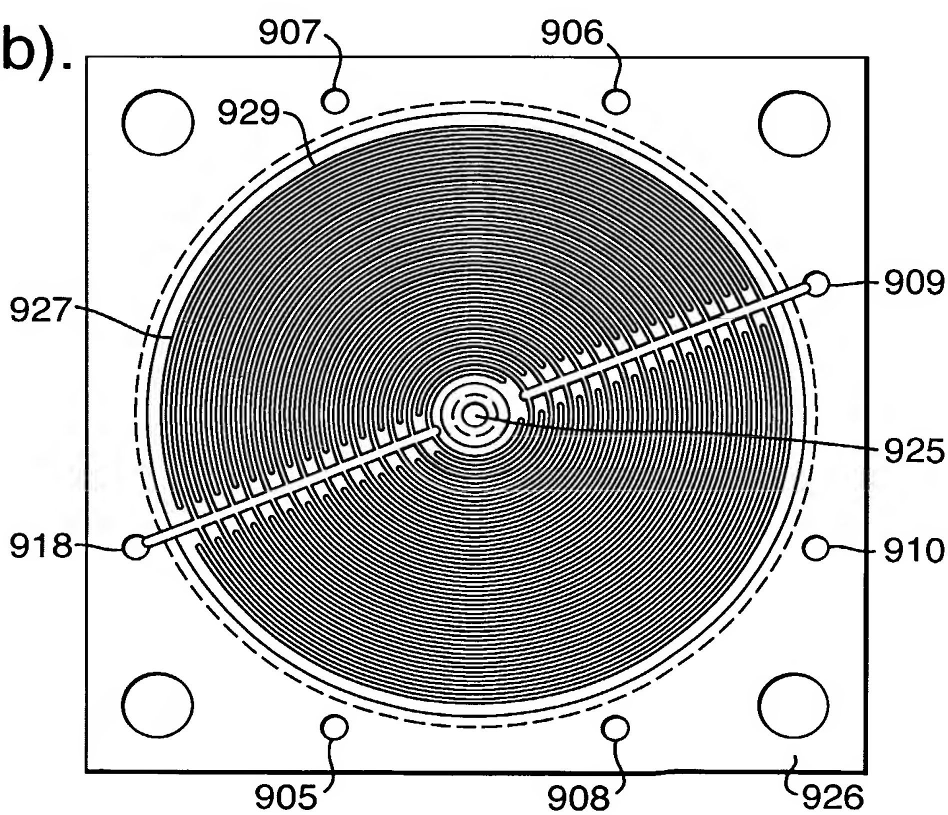


Fig.14(a).

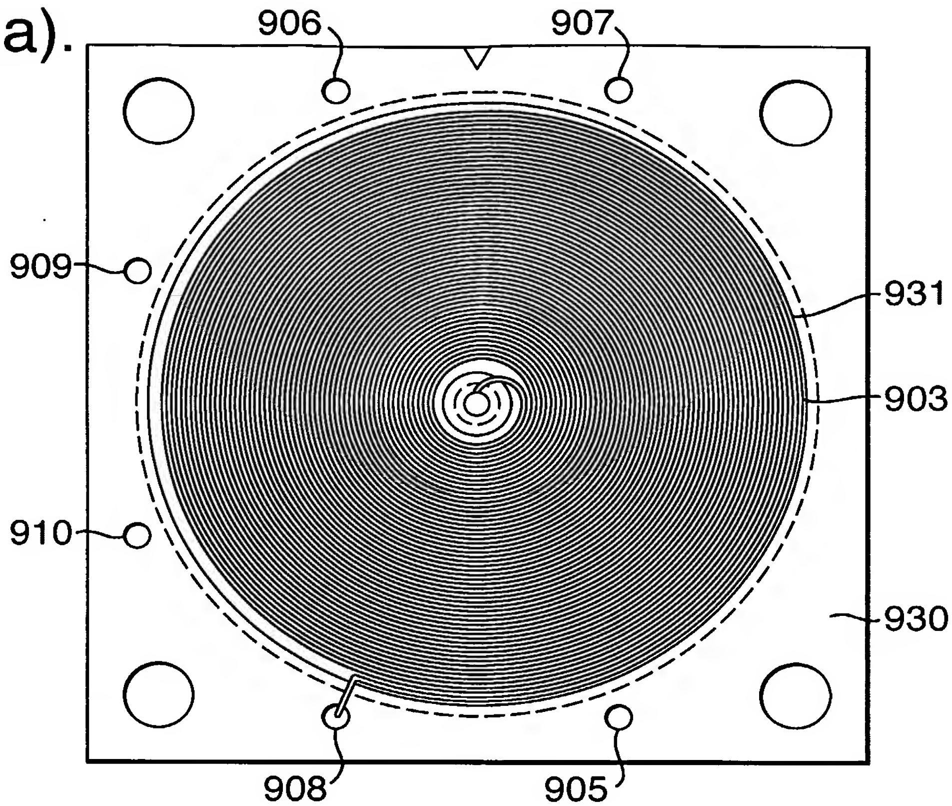


Fig.14(b).

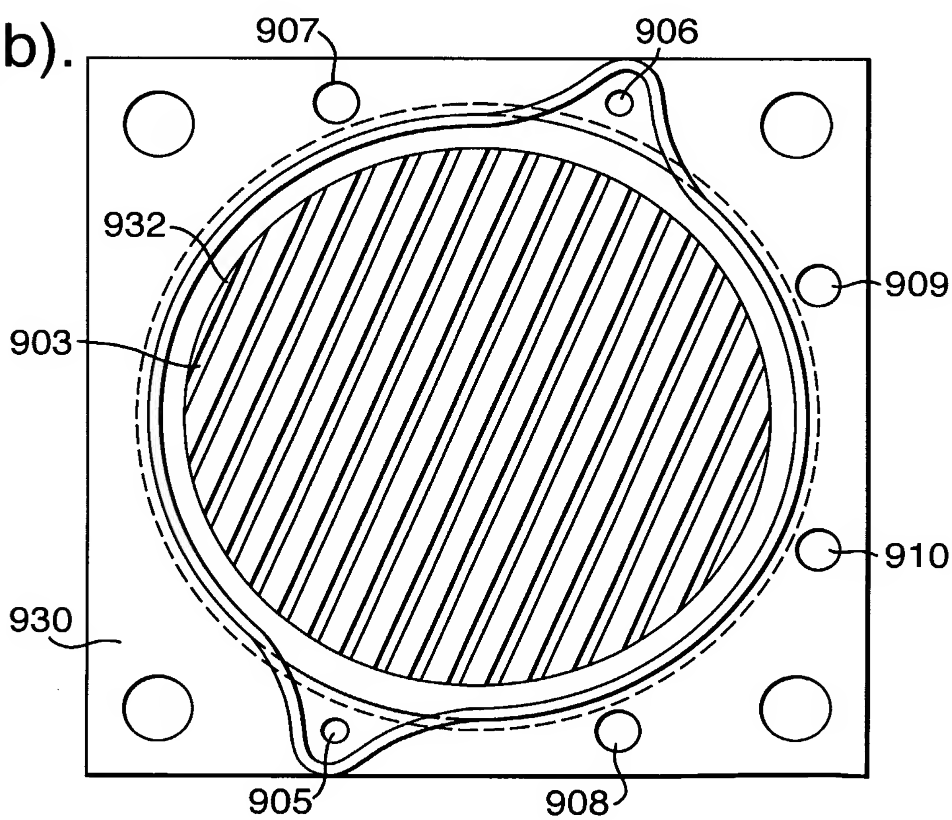


Fig.15(a).

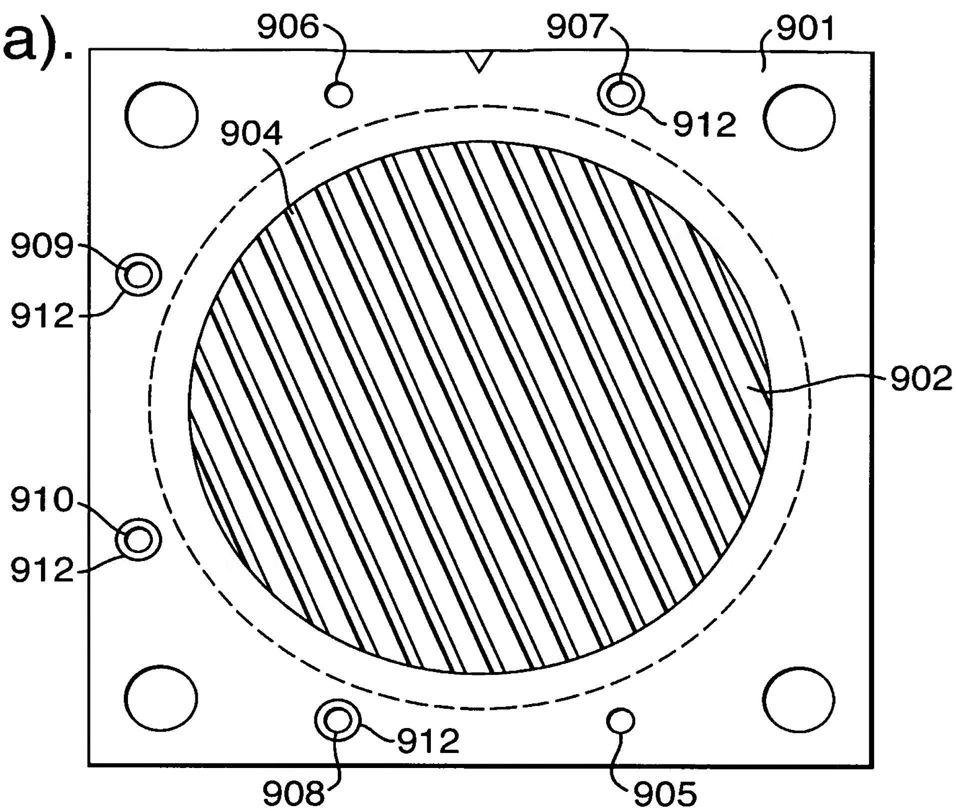


Fig.15(b).